9th AIAA Aviation Technology, Integration, and Operations Conference (ATIO)
and
Air
21 - 23 September 2009, Hilton Head, South Carolina

AIAA 2009-7012

JPDO Portfolio Analysis of NextGen

Yuri Gawdiak[1]
Joint Planning and Development Office, Washington, DC, 20005

The Next Generation Air Transportation System (NextGen) represents the transformation of the National Airspace System, including our national system of airports, using 21st century technologies to ensure future safety, capacity and environmental needs are met. NextGen will be realized through investments in research and development, technologies, operational changes, and the coordinated efforts of private industry and federal NextGen partner agencies, including the Federal Aviation Administration (FAA); the Departments of Transportation (DOT), Defense (DOD), Homeland Security (DHS), and Commerce (DOC); the National Aeronautics and Space Administration (NASA); and the White House Office of Science and Technology Policy (OSTP). NextGen is a collaboration among these Federal agencies and aviation stakeholders to meet the increasing demand for efficient and affordable air transportation services. Among its research, development, and coordination activities, the Joint Planning and Development Office (JPDO) is charged with analyzing the costs, benefits and risks of NextGen. In response to federal budgeting requirements and the Office of Management and Budget (OMB) reporting requirements for the Fiscal Year 2011 (FY2011) budget, this year the JPDO has developed a Portfolio Analysis package that serves as the basis for a full NextGen Business Case. The NextGen Business Case is expected for the FY2012 budget.

I. Introduction

In order to generate the components required for a complete business case, the JPDO completed the initial analyses and studies documented in this year's NextGen Portfolio Analysis. The portfolio analysis is the process of identifying and enumerating the costs, benefits, and risks of possible NextGen alternatives. It is expected one or more of these alternatives will be used to make the business case for the long-term strategic investments in NextGen.

Major activities in the current portfolio analysis include:

1. Modeling, simulation, and analysis of the future National Airspace System (NAS) based on a ground-centric and highly-automated initial alternative (i.e., the Initial Alternative) of NextGen guided by the JPDO NextGen Enterprise Architecture (EA) and Integrated Work Plan (IWP)
2. Development of operational and financial performance metrics
3. Analysis of environmental impacts
4. Development of additional NextGen alternatives based on adjusting one or more of the following components: equipage levels, Operational Improvement (OI) performance levels, Initial Operational Capability (IOC) dates, specific policy assumptions, and adjustments to acceptable risk exposure levels
5. Estimation of lifecycle costs for the Initial Alternative
6. Estimation of risk-adjusted rough order of magnitude costs for select ground systems and avionics
7. Initiation of risk analysis of the research and development activities.

The JPDO NextGen Portfolio Analysis Report initiates a critical feedback process for the JPDO products by identifying the comprehensive cost, benefits, and risks of the alternatives within EA and IWP. It is expected that the ongoing portfolio analysis will help the NextGen community make appropriate adjustments and augmentations to JPDO products to help ensure a successful NextGen initiative.

[1] Director, Interagency Portfolio and Systems Analysis Division, 1500 K St., Washington, DC, Member AIAA

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **SEP 2009**	2. REPORT TYPE	3. DATES COVERED **00-00-2009 to 00-00-2009**
4. TITLE AND SUBTITLE **JPDO Portfolio Analysis of NextGen**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Joint Planning and Development Office,1500 K Street NW Suite 500 ,Washington,DC,20005**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**22**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

II. Summary Results and Findings of Portfolio Analysis

A comprehensive cost-benefit analysis of the Initial Alternative of NextGen shows the potential for a positive Net Present Value (NPV) by FY2050. However, if the research and development risks and environmental impacts (including climate change) are factored into the analysis, the NPV could range from a negative value to a positive value by FY2050. Other potential alternatives are being investigated that might mitigate the effects that could result in a negative NPV.

As a result of conducting the studies and analysis to generate this estimate, several findings emerged. The Portfolio Analysis helped the JPDO identify several major analytical and policy issues that need to be addressed in the near term:

Environmental Goals. The largest influence on the portfolio trade space is the environmental policy approach. In particular, how the long-term climate impacts are dealt with, including assumptions regarding the monetization of these effects, can lead to widely-varying results. A policy decision should be made regarding environmental goals and assumptions and methods to be used in monetizing environmental impacts (such as environmental performance targets and discount rates). If the more conservative environmental targets are used, then there will be very significant challenges and a more aggressive environmental strategy will be required to meet NextGen goals. The current JPDO analysis has used moderate environmental targets and the ensuing results show that the benefits of planned NextGen R&D activities will offset environmental costs.

Risk Assessment. The complexity of the air transportation system, and the current state-of-art for verification and validation (V&V), carry a high risk that the performance, schedule, and costs of the current NextGen that the entire IWP will not be accomplished by 2025. Due to the large uncertainty of the potential risks, a detailed analysis of cost risks of the Initial Alternative and other NextGen alternatives is needed to inform the development of risk mitigation strategies and to evaluate the feasibility of different NextGen alternatives under consideration. Since equipage requirements and major policy decisions have long-term implications, they should be fully evaluated in the near-term to ensure fully informed decision making by the NextGen community and partners.

Cost Feasibility. NextGen alternatives that are feasible from a performance and risk standpoint must also meet cost feasibility constraints. In particular, commercial airlines and operators of high-performance general aviation aircraft (such as business jets) may not be able to finance the equipage costs that would enable full NextGen capabilities. Viable alternatives that meet cost constraints must have associated policies that recognize market factors contributing to the willingness of stakeholders to invest in NextGen.

Performance Metrics and Targets. A set of minimum performance requirements must be made explicit and tied to broad NextGen goals. Without the explicit knowledge of specific target levels, a comprehensive evaluation of alternatives is not possible. Given the complexity of the NextGen systems and stakeholder interests, reaching the appropriate target levels will require an iterative approach where decision makers can test different targets, and forecast the impacts to the system and stakeholders.

III. Portfolio Analysis

A. Purpose

The purpose of this document is to establish a structure and begin to assess and investigate the incremental benefits, corresponding costs, and risks associated with NextGen modernization of the air traffic management system. There are multiple stakeholders involved in the implementation of NextGen, therefore, the JPDO's approach is to focus on identifying key performance measures and values that are important, not only to the overall system, but to individual stakeholders. Interpreting and valuing performance measures based on stakeholder objectives, and illuminating their different perspectives, is critical to understanding and justifying the resources necessary for NextGen modernization. By further laying out the scope and rationale of NextGen, considering cost, performance, risk and value to the nation and aviation stakeholders, the portfolio analysis serves to engage a broader audience in the public and private sectors, and aids in examining and driving the critical investment decisions required to realize NextGen.

This portfolio assessment is the first time a quantitative cost/benefit and risk analysis has been aligned and conducted on a significant subset of the capabilities in the NextGen Integrated Work Plan (IWP). These results will be used to aid in strategic multi-agency decision making. Those results will be reflected in the adjustment and validation of the NextGen planning documents, specifically the maturity and feasibility of the elements within the IWP and EA. Because NextGen involves various programs, research activities and systems that are in various phases of maturity and implementation, the EA will continually be refined. Refinements include iterative enhancements to critical OIs and Enablers, involving close collaboration with the stakeholder community to obtain clearer descriptions of the proposed solutions and associated performance needed to achieve these NextGen improvements and capabilities. The JPDO portfolio analysis is intended to improve the quality and accuracy of the NextGen planning documents by providing feedback that is based on cost, benefit, and risk methodologies and to align and improve the strategic planning process.

It should be recognized that monetizing the benefits to each of the stakeholders at best offers a glimpse into one specific dimension of the NextGen portfolio, rather than the entire portfolio. Within the tradespace of possibilities for the NextGen system, there are too many variables and embedded assumptions for the assessment of one alternative or one particular stakeholder to constitute a complete and accurate assessment of potential value. The monetized estimates assume specific actions and uses by each stakeholder of NextGen improvements, but to state that these estimates represent an accurate portrayal of the complete future value is unrealistic. The benefits, NPV, and cost/benefit ratios should be used to understand how operational improvements could potentially be used to create value and should be employed to discuss potential trade-offs among stakeholders and alternatives to a possible NextGen system in the context of the overall portfolio analysis.

B. Scope

The JPDO Portfolio Analysis is challenging by the nature of the scope and complexity of NextGen which, over time, demands a transformation of the entire air transportation system. The total system includes not only known needs in the form of hardware, software, infrastructure, facilities, runways, air traffic management procedures, civilian use of military airspace, and advanced avionics, but also research and development to both transition into the near- and mid-term horizons and to fuel innovation for less-defined far-term NextGen capabilities, and the integration and interoperability of management systems such as net-centric information sharing, environmental, safety, and security management systems. Additionally, NextGen is clearly more than technological changes. NextGen encompasses the roles and responsibilities of the organizations and people that operate and use the system and the policies and processes that govern its operation. The total system must also simultaneously address multiple objectives, including increased capacity, improved efficiency, improved safety and security, and reduced environmental impact. Lastly, although NextGen is commonly referred to as a “system”, NextGen is really a “system of systems” for which there are multiple business models.

The original scope for this year was to estimate the costs, benefits and risks for NextGen as defined in the NextGen IWP. The IWP contains a comprehensive set of multiple performance levels for NextGen rather than a single prescribed path to the future. In order to conduct a portfolio analysis, the JPDO selected one representative path to evaluate the costs, benefits and risks to a subset of stakeholders. It is referred to in this report as the Initial Alternative – Ground-centric Automation. The metrics, costs, benefits and risks of this one specific IWP iteration will be the primary focus of the following summary of results (Sections 2, 3, 4 and 5). The interim results from this analysis established that the costs and risks associated with all stakeholders complying with complete NextGen transformation by 2025 did not appear feasible. What this analysis accomplished was to establish a business case evaluation framework to conduct further portfolio assessments.

JPDO has begun to evaluate alternative portfolios to achieve NextGen and to refine the IWP. At this point, the JPDO has taken a first step by developing ROM (rough order-of-magnitude) cost estimates for differing levels of performance and investments by stakeholder. These results will be presented in this document (Section 6 – Secondary Alternatives Cost Analysis). It is the JPDO’s intent to build upon this work to refine the portfolios and test them under future scenarios that consider different policy objectives and operating environments and estimate the corresponding stakeholder benefits.

This year’s portfolio analysis focuses on those operational improvements, associated costs and risks directly attributable to airports and air transportation services. It includes research costs from NASA and some investment

costs from DOC, but it does not include operational improvements and benefits associated with defense and homeland security, specifically investments from the DOD or the DHS).

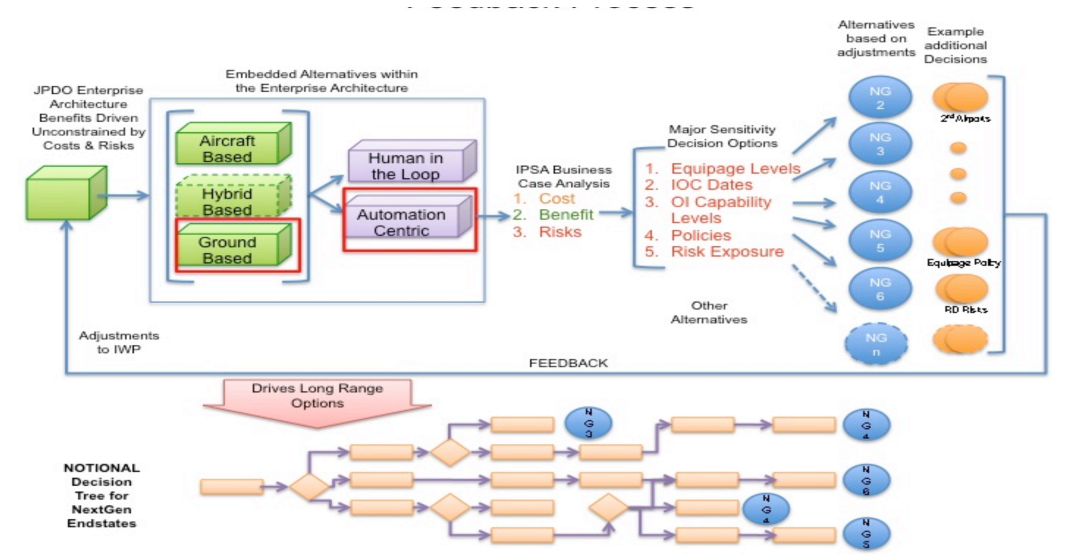


Figure 1 Portfolio Tradespace Exploration and Feedback Process

C. Initial Alternative – Ground-Centric Automation

There are multiple choice and technological options available that could potentially deliver NextGen capabilities. More advanced capabilities which fully capitalize on shared digital information and satellite positioning precision still require some refinement and research before requirements are completely defined to implement the capability. One of the basic investment and operational choices to be considered for many of these advanced capabilities is whether the technology and automation should be a component of the ground infrastructure or should be integrated into the aircraft avionics suite.

The initial analysis for this year selected one alternative, or path, to achieve all NextGen capabilities based on the JPDO EA as reflected in the JPDO IWP. An "Executable" Architecture was constructed based on the IWP and EA to estimate the costs, benefits and risks of NextGen. The selected path targets a portfolio that has a ground-centric focus. It is consistent with the FAA's plans through the mid-term period (approximately 2015-2018). This alternative still requires enhanced avionics, but not to the full extent that may be considered to realize NextGen capabilities. This distinction is critical for the Initial Alternative case, especially for estimating the cost of NextGen. For example, an alternative path that placed more technology and capability into the aircraft would have a much different cost profile than the ground-centric alternative that was chosen for the portfolio analysis. Our analysis indicates that this particular alternative has significant challenges in terms of costs and development risks for full implementation by the year 2025. The goal of the portfolio analysis report is to inform the community and help provide valuable feedback in adjusting and/or updating the IWP.

The following summary and table details some of the high level choices that were made to specify the Initial Alternative. These basic choices were used to construct a more detailed "Executable" Architecture from the NextGen IWP and to estimate the costs of NextGen in this portfolio analysis.

<u>Summary and Rationale for Key Choices:</u>

- Ground vs. Aircraft based Trajectory-based Operations – Assumed continued Air Navigation Service Provider (ANSP) ground-based automation is a more likely path and redundant systems in the aircraft is not cost-effective
- Limited Airspace Reconfiguration – Currently there is not much information available on the benefits of fully dynamic airspace

- Reduced Separation Operations – With ADS-B Out and Trajectory-based Operations, 3 nautical miles (nmi) separation during en-route flight should be achievable
  - Will not include an operational improvement that specifies going below 3 nmi for arrivals and departure because it may not be possible and not much information on the added benefit
- Special Aircraft Variable Separation Standards – Due to limited and targeted application, it is not included in the alternative
- Integration of Weather Information into Dynamic Scheduling System (DSS) – ensure that current weather conditions are integrated into scheduling systems to make real-time adjustments especially in adverse weather situations.

Table 1 Initial Alternative and Options

	NextGen Portfolio Option 1	NextGen Portfolio Option 2	Initial Alternative
Trajectory-based Operations	Ground-based Separation and Trajectory Management	Flight deck-based Separation and Trajectory Management (i.e., self separation)	**Ground-based Separation and Trajectory Management**
	Limited Dynamic Reconfiguration	Fully Dynamic Airspace Reconfiguration	**Limited, Dynamic Airspace Reconfiguration**
	5 Mile Separation	3 Mile Separation	**3 Mile Separation**
	Variable Separation	No Variable Separation	**No Variable Separation**
	Conventional Surveillance Radars and Navigation Backup	E-LORAN Backup	**Conventional Surveillance Radars and Navigation Backup**
Weather	Full Weather Information / Integration into the Automation	Limited Weather Information / Integration	**Full Weather Information / Integration into the Automation**
	Additional Aircraft Sensor Integration	No Additional Aircraft Sensor Integration	**No Additional Aircraft Sensor Integration**
Environment	MITRE Fleet Forecast – without consideration of environmental issues	MITRE Fleet Forecast + new aircraft (Continuous Low Emissions Energy and Noise (CLEEN)	**MITRE Fleet Forecast + new aircraft (CLEEN). New A/C inserted at the projected A/C retirement rate**
	Environmental Limits will Constrain Throughput	Not a Constraint	**Not a Constraint**
High Density Airports	Vertical Required Navigation Performance (RNP)/ either Flight Management System (FMS)/ Cockpit Display of Traffic Information (CDTI) or Airborne Merging & Spacing with Automation Tools (Full CDAs with no capacity impacts)	Limited CDAs	**Vertical RNP/ either FMS/CDTI or Airborne Merging & Spacing with Automation Tools (Full CDAs with no capacity impacts)**
	Ground Surface Traffic Systems (additional terminals/gates) – 45% Limit	Limits Demand	**Ground Surface Traffic Systems (additional terminals/gates) – 45% Limit**
Collaborative ATM (HD)	Traffic Management Advisory (TMA) ++, Time Based Metering	Airborne Metering	**TMA ++, Time Based Metering**
Equipage Profile Curve	100% by IOC Date	Less than 100%	**100% by IOC Date**
Rules of the Road (pay to play)	All Aircraft Equipped	Different fleets treated differently (different % of equipage)	**All Aircraft Equipped**

IV. Framework for Assessing Stakeholder Benefit, Cost, Risk and Uncertainty

A. Approach

The overall approach to the Initial Alternative case is to use the plans, investments and improvements described in the NextGen EA to estimate the costs, benefits and risks of NextGen to society and to major stakeholders in NextGen. The process uses the underlying components of the IWP and translates them into an "Executable" Architecture that can be aligned and compared with supporting agency plans and architectures. The benefits analysis uses the OIs specified in the IWP to simulate the projected operational changes with NextGen compared to a future without NextGen (also called "the baseline"). The cost estimates employs the enablers from the IWP to determine the investments required to support NextGen capabilities. Details of the supporting methodologies for costs, benefits, and risks are contained in the supporting documents.

A primary objective for this Initial Alternative case is to estimate the costs and benefits for a subset of air transportation stakeholders and provide a more complete analysis of the trade-offs that decision makers should consider for all stakeholders, in terms of the National Airspace System goals of Capacity, Environment, Safety, and Security, laid out in the Vision 100 legislation. In addition to establishing stakeholder metrics, the JPDO must incorporate and make assumptions about the projected business environment of the stakeholders and how they will leverage potential operational benefits. These estimates should also contain an uncertainty/risk adjustment to provide decision makers a sense of the volatility of possible outcomes under different scenarios. At this time, the JPDO has only begun to assess risk implications and uncertainty by stakeholder. In future analysis it is expected that the JPDO will provide a wider range of possible outcomes under different scenarios.

The JPDO believes a stakeholder portfolio assessment is critical to the air transportation community to make informed decisions. These estimates must include an explanation of the underlying assumptions and uncertainty to provide an accurate depiction. There are far too many variables and stakeholders to be considered in a long term forecast for a single return on investment number to convey the appropriate information. It is important, but it must be used in context with other information and factors that contribute to an assessment of NextGen. The SESAR (Single European Sky ATM Research Program) has also estimated the cost and benefits to stakeholders and has emphasized the need to consider the numerous ways that operational improvements can be turned into value. It also recognizes the need to develop scenarios and assumptions that provide the foundation for future return on investment estimates.

An important consideration when developing a business case for any stakeholder is that in many cases, operational improvements that may appear to be of obvious value to one stakeholder in the system may have negative implications when overall costs, benefits and risks are considered. For example, NextGen is expected to increase the number of flights in the NAS. From an initial common sense perspective, additional flights should be valuable to commercial airlines and passengers. But additional flights may not increase the bottom line for all commercial carriers or the industry as a whole. If a commercial carrier cannot cover the costs of providing the additional flights, this new capacity becomes a losing proposition for the airline. This is just one example of the possible trade-offs and scenarios that need to be considered when developing stakeholder metrics. Because operational improvements may have different values across stakeholders, and even among the same stakeholders, the JPDO is considering multiple stakeholder metrics. Developing these metrics is a key step to convert operational improvement results into value that can be used to derive cost and benefit estimates and assess resulting stakeholder trade-offs.

B. Major Assumptions

The Initial Alternative analysis contains some overarching assumptions that are critical to the development of estimates and interpretation of results. These assumptions define the overall "alternative" of the environment that will be reflected in the following results of the Initial Alternative case.

Timing: The Initial Alternative analysis assumes that all the identified OIs are implemented by 2025 and that full equipage of aircraft is achieved to obtain maximum benefits associated with these OIs. The one exception is High Performance General Aviation. Preliminary analysis determined that full equipage for High Performance General Aviation by 2025 was prohibitively expensive and may not be technologically feasible. Changes in the timing profile of equipment or when the operational improvements become operational would significantly change the results of the analysis. These implications are examined in Section 6: Secondary Alternatives Cost Analysis.

Unconstrained Resources: It is assumed that all the capabilities as defined by the JPDO are funded and all supporting equipment purchased by 2025. This includes agency expenditures, private investments such as avionics, and local supporting infrastructure (e.g., airport investments by state and local authorities). Any constraints in funding or delay in implementation of infrastructure alters the Initial Alternative case. Adequate funding, and in the years it is required, are critical assumptions, especially for a transformation that entails a large dedicated funding stream for both research and implementation for a long period. A significant part of the investment equation is in the government's control, but for a successful transformation, investments in avionics and airports must also be made.

Environment: Potential environmental outcomes did not constrain the estimate to accommodate potential future demand. The potential monetary results of the environmental impacts will be factored into the society/passenger business case.

Economy and Capacity: The increase in demand forecasted by the FAA Terminal Air Forecast (TAF) is predicated on the overall assumption that there will be a "reasonably" healthy air transportation service operating in the U.S. and globally over the next 20 years. While there may be some debate about secondary contributing factors that impact aviation growth, most forecasters agree that domestic economic growth [(Gross Domestic Product (GDP)] and price of air travel (fare and/or yield) are primary factors that drive demand. Therefore, the assumption is that these factors will continue to propel the demand for air transportation service. One of primary objectives for NextGen is to build an air transportation system that can efficiently handle future growth in demand. For the most part, this implies that air travel continues to grow at a rate that is consistent with leading aviation forecasts. There may be differing underlying assumptions depending on the forecast, such as size and type of aircraft, which can elevate or decrease the demand anticipated, but used in the context as an overall target for needed capacity in the future, it is a reasonable expectation, not out of line with current projections in the aviation community.

Infrastructure and Avionics: To meet NextGen goals and objectives, it is assumed all required aircraft avionics are installed that complement the NextGen infrastructure. Adequate avionics equipage may be a greater challenge for NextGen than infrastructure deployment. Currently, purchase of avionics equipment is borne by the user and there is no explicit requirement for users to purchase NextGen avionics. The Initial Alternative case assumes whether through policy, mandate, incentives or other means, aircraft will be compatible in accordance with NextGen performance requirements.

Airports and Runways: Runways are constructed at major airports comparable to historic growth rates. The assumption is that 15 runways will be added by 2025 (extracted from the FAA Operational Evolution Partnership document and major airport strategic plans).

Marginal Evaluation: The analysis is based on comparing the results of a future with NextGen transformation and a future that maintains the current system, which is referred to as the baseline case. All estimates are based on comparing these two hypothesized futures. For example, to estimate the increase in additional flights from NextGen investments, the difference is taken between the baseline future case versus the NextGen case. It is a marginal or incremental estimate.

Stakeholders: The Initial Alternative analysis provides the financial results for the following stakeholders that are key players providing air transportation services: overall society/passenger, commercial airlines, air navigation service provider (Federal Government/FAA), airports, and high performance general aviation. It does not include some important stakeholders, such as cargo, military and other general aviation categories.

Lifecycle Costs and Benefits: The lifecycle cost and benefits for the Initial Alternative encompasses the 2010-2050 period. Costs and benefits include both NextGen Operational Improvements and additional runways.

C. Metrics

The JPDO Interagency Portfolio & Systems Analysis (IPSA) division continues to coordinate, develop, and refine the metrics and targets associated with the NextGen initiatives with the partner agencies & stakeholder communities. IPSA has formulated a set of top-level metrics as indicators of progress toward the six goals established in the 2004 National Plan. Stakeholder metrics, reflecting system performance from the point of view of specific stakeholders, are being formulated to assess and communicate the benefits of NextGen to specific stakeholders. Most of these metrics are calculated from system performance measures that constitute outputs of the

IPSA modeling and analysis activity, others reflect data obtained from the JPDO partner agencies. A set of these performance measures is also used to support the business case for NextGen.

Top-level metrics are currently being calculated for the goals related to Capacity and Environment, and top-level metrics have been suggested for Global Leadership, Safety, National Defense, and Security, but they still require refinement. The capacity and environment metrics are currently used to calculate benefits expressed as monetary values in formulating the business case and stakeholder valuations.

Work to date has identified several issues in developing suitable metrics for NextGen. For example, metrics for NextGen must be based on projected performance of the future system, but they should also be reconcilable with other current and future measures of actual performance, particularly those being used by the FAA and other participants. Actions are underway or under consideration to address the issues identified to date.

Stakeholder metrics are intended to reflect how key stakeholders value the performance and other attributes of NextGen. An initial set of such metrics has been developed in conjunction with the portfolio analysis and will soon be matured through interactions with stakeholders and other planned actions. These metrics, along with monetized results for stakeholders, will be the focus of this document.

V. Benefits Analysis

We accomplished this analysis using the NAS-wide modeling and simulation tools that have been brought together from a number of organizations for use in the IPSAD. The performance benefits that might result from the NextGen capabilities were estimated on a relative basis compared with the estimated performance of a "Baseline" NAS that does not include NextGen capabilities. The approach taken for this evaluation was comprised of five major steps: 1) estimation of the impact of the NextGen Initial Alternative Operational Improvements on airport and airspace capacities (OI abstraction), 2) development of future demand scenarios based on FAA TAF forecasts, 3) evaluation of baseline NAS performance for different levels of future traffic), 4) evaluation of the NextGen performance for different levels of future traffic, and 5) comparison of the NextGen performance and the Baseline performance. The primary measures of NAS performance related to capacity include the throughput of the system, and the associated delays required to balance demand with available capacity. We therefore estimated the number of flights that can be accommodated at reasonable levels of delays in good weather. In addition to estimating the performance benefits related to NAS capacity in good weather, we evaluated the performance of the Baseline and NextGen scenarios as measured by average flight delays in poor weather as well as the environmental performance of the Baseline and NextGen scenarios.

A. Throughput vs. Delay Tradeoff and Project Throughput

It is often said that air system capacity and air system delay are two sides of a single coin, linked by the amount of load or user activity within the system. For example, if capacity is held constant and load on the system (throughput, or user activity in the form of flights) is increased, then average system delay increases. Conversely, if system delays are to be held roughly constant in the face of increasing load on the system (throughput), capacity must increase by an appropriate amount in some way. The users of the system ultimately decide, through their scheduling practices, at which point the system operates along the delay/throughput curve. In addition to such a curve associated with the current system, a new curve can be envisioned associated with the capacity enhancement provided by NextGen or any other NAS investment. The investment provides benefit, assuredly, but that benefit can be taken as additional throughput, reduced delay, or some combination of the two. These concepts and curves are depicted in Figure 2.

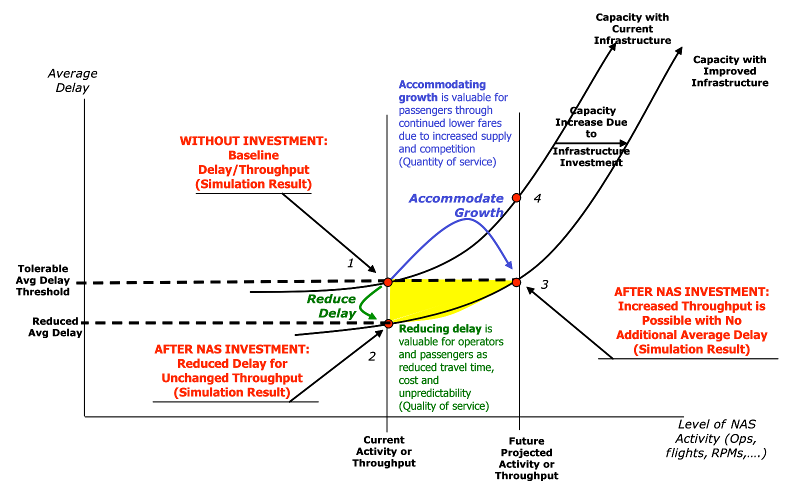


Figure 2 Graphical Depiction of Delay/Capacity Tradeoff

Many traditional NAS benefits analyses have focused on the delay reduction aspect of the tradeoff. But for more transformational changes to the system, we believe the additional throughput aspect may be more appropriate. Future demand forecasts such as the FAA TAF represent unconstrained demand; i.e., there is no accounting for airport and airspace capacity limitations. Our thesis is that at a certain saturation point, some of the demand would go unsatisfied in order to keep delays at tenable levels. We reasonably assume that the airlines, being in the business of providing reliable transportation, will not schedule a service if its expected delay exceeds some delay tolerance. Therefore, as a composite capacity metric, we use the concept of "projected throughput." This is the daily number of flights that can be accommodated by the system given (1) an airport-specific demand/capacity ratio (explained further below); (2) a sector-specific maximum airspace capacity; and (3) assumptions about the airline business model (e.g., scaled-up current system, business shift to alternate airports, introduction of large numbers of Very Light Jets (VLJs)). Projected throughput thus measures how much of forecasted demand can actually be accommodated by the system.

Prior analyses have shown that if future demand is allowed to grow at a pace that outstrips the planned growth in capacity, the delays that would be experienced in the NAS would become unrealistically large. We therefore used a method of constraining future demand by trimming flights from the projected demand to maintain reasonable levels of delay in the NAS. In this manner we were able to quantify the future shortfall in NAS capacity by measuring the number of flights that must be removed from the projected or unconstrained demand. We then compared the capacity shortfall for the future baseline NAS with the capacity shortfall of a future NAS using assumed increases in airport and airspace capacities to represent the operational impact of the NextGen capabilities. The NextGen capabilities should reduce the capacity shortfall and enable the NAS to accommodate a greater number of flights while maintaining a reasonable level of delay – i.e., the projected throughput should increase under the NextGen scenario.

The demand/capacity (D/C) ratio is typically used to characterize an airport's ability to serve the traffic demand (number of operations) placed upon it, given its total runway capacity (also measured by number of operations). This metric is measured over a period of time (e.g., an hour or a day); it is not typically used to measure en route performance. Queuing theory, backed by quantitative data analysis, indicates that for efficient operations an airport's D/C ratio must be less than 1.0, otherwise delays build up exponentially which would severely compromise an airline's ability to maintain schedule integrity. The D/C ratio can exceed 1.0 only for short periods of time. In recognition of this, we limit each airport's D/C ratio to 1.2 for each 15-minute epoch and to 0.9 for each rolling hour. Our model computes the D/C ratio throughout the day, at each airport, for both arrival and departure queues. If the ratio exceeds our tolerances, we reduce the demand to conform to this constraint. For the airspace, we use the FAA's sector Monitor Alert Parameter (MAP) to represent each sector's maximum capacity.

Flights are selected for elimination, one flight at a time, based on criteria that measures the flight's total impact on congestion at the airports and in the airspace (sectors) in which that specific flight operates. Finally, when the new constrained schedule (in which flights have been eliminated to satisfy our airport D/C and airspace MAP value

constraints) has been created, we compute various traffic measures for benefits, such as flight operations, available seat miles, and revenue passenger miles. These measures are what we refer to as the projected throughput. We realize that flight elimination is an extreme method of handling capacity constraints. Alternatively, flights could be shifted to other times and/or take different routes. However, these strategies are airline coping mechanisms (using larger aircraft is another strategy). Flight elimination, and the concept of projected throughput in general, is an analytical construct meant to measure the shortfall between capacity and demand; this construct assumes that airlines operate the way they do currently for rational reasons and would seek to preserve that operating mode. The possible coping mechanisms all have costs and tradeoffs associated with them.

B. Valuation Approach for Additional Throughput and Reduced Delays

As described in other sections, the various operational improvements and other enhancements and innovations that will make up the NextGen Air Traffic Management System offer new capabilities and opportunities to future users of the nation's airspace. These users will rely on these capabilities and opportunities for improved system access and system flow to increase and improve the services they provide to their own growing and more demanding customer populations. From a societal perspective, benefits from the NextGen improvements stem from the increased value that NAS users can provide to these customers – passengers, shippers and others. This increased value may take many forms, such as increased system throughput and activity, allowing transportation to be provided to a larger number of customers, and improved service qualities, such as reduced passenger and aircraft delay or more reliable and predictable service.

One approach used in this analysis for estimating the value of the NextGen capabilities and improvements for the future NAS is to compare the operational throughput of an air traffic system with those NextGen improvements and its throughput in a baseline or status quo state, while holding average delay (or demand/capacity ratios) at airports roughly constant. Holding a delay or demand/capacity ratio parameter roughly constant in the two simulations is a proxy for maintaining rough parity in transportation service quality for the comparison. The demand generation and flight trimming techniques described elsewhere in this analysis are then used to simulate the performance of the NextGen system and the baseline system, and a comparison is made between the number of commercial passenger revenue passenger miles (RPMs) that can be flown in the NextGen system and the number of commercial passenger RPMs available in the baseline system. These RPM estimates are based on the commercial passenger fleet assumed for future operations, with RPMs derived from ASMs flown using a conservative load factor estimate of 82%. Annualized ASMs flown are in turn derived from assumptions on average aircraft seat size within the fleet and the annualized number of commercial passenger operations flown in each of the two systems (NextGen and baseline).

The economic significance of this difference in feasible passenger service throughput for any given year is estimated by estimating a demand for domestic RPMs, using the FAA Aerospace Forecast of domestic passenger service activity (in RPMs) and average domestic real yield (inflation-adjusted revenue per passenger mile), developed by FAA economists and market analysts. These forecast values are treated as an equilibrium price and quantity pair in an aggregate national market for domestic air travel, and a constant price elasticity market demand curve can be located through this point to represent market demand in that year. Any reasonable value can be used for this constant elasticity demand curve, but for these analyses a price elasticity of –1.0 is used. This value is consistent with the range of values observed in the academic literature for the elasticity of demand for air travel.

With the assumed demand curve in hand, it is possible to compare the simulation-based domestic RPM feasible throughput for the baseline system and for a system that has had its performance improved through the deployment of one of the High Density Case NextGen scenarios. Using the demand curve, a market clearing average domestic real yield can be imputed for each RPM total. With the customary downward sloping demand curve, a higher number of annual domestic RPMs (which would be made possible through NextGen system enhancements to the baseline system) implies a lower market clearing average domestic real yield, other things equal. It is this economic relationship that is used to develop the valuation of enhanced throughput based on changes in consumer surplus for travelers.

Several simplifying assumptions go into this estimation method. The shape of the demand curve is one such assumption, although the calculation of a change in consumer surplus is affected by this assumption only along the range of yield or annual RPM variability used in the analysis. The shape of the demand curve at very low levels of annual domestic RPMs (and very high average real yields), which may be more controversial or uncertain, does not enter into the calculation. It is also assumed that the yield and quantity pairs move along the demand curve, and that

competition in the airline industry along with airline cost changes resulting from NextGen improvements make these yield changes feasible for airlines whose collective output grows to take advantage of improved throughput possibilities. If there are cost or other types of constraints affecting the ability or willingness to provide additional RPMs to passengers at lower average fares, the analysis may require further refinement. What is measured by the consumer surplus calculation is the value to passengers of the availability of increased throughput (due to the improved capability of the NextGen system) due to the resulting lower average yields necessary to clear an expanded market.

This approach to estimating the value of NextGen for passengers follows from an assumption that system users respond to the NextGen improvements by increasing throughput and leaving system service quality largely unchanged for passengers. In Figure 2, this is equivalent to a move from the baseline system throughput/delay tradeoff point 1 to the NextGen system throughput/delay tradeoff point 2, which results in increased throughput relative to the baseline but an unchanged level of average delay.

A second approach to characterizing and valuing the response by domestic passenger airline users of the NAS to the improved NextGen capabilities results from assuming that carriers "consume" all the improved capabilities in the form of reduced delay while leaving the level of throughput unchanged from the baseline scenario outcome. Such a characterization results in no additional flight services in the domestic passenger market, but does result in an improvement in average flight times and service quality. Figure 2 can again be used for a graphical representation of this approach, which is equivalent to a move from the baseline system throughput/delay tradeoff point 1 to the NextGen system throughput/delay tradeoff point 3.

The value to system users and their customers of this approach can be approximated by estimating the total annual minutes of delay that are avoided due to the move to the NextGen throughput/delay tradeoff curve, and then monetizing this effect. This effect can be monetized using the value of time to passengers and the value of direct operating costs that are avoided by airlines when flight delays are reduced on average.

These two approaches to estimating the monetary value of NextGen improvements for domestic passenger operations and their passengers rely on holding constant one of the two major capacity variables affected by NextGen. Simulation results should then focus on the improvements that can be attained for the other.

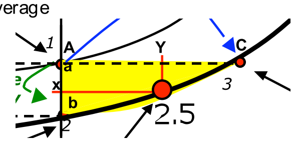
Such a restriction also makes the calculation of monetary value much more direct than is possible for a more realistic outcome, in which both variables of interest – throughput and delay – are allowed to vary within the simulation. Because at such an intermediate point – which can be called in general "point 2.5" lying somewhere along the NextGen throughput/delay tradeoff curve – both the quantity and the quality of output change, direct computation of a monetary valuation is difficult. A "hybrid" valuation approach has been developed.to overcome this hurdle while providing a valuation for intermediate points that is consistent with the two approaches described above.

The details of the hybrid valuation approach can be seen in Figure 3 below. This figure focuses on the central portion of the NextGen impact shown more generally in Figure 2. For any particular intermediate simulation point (known generically as "Point 2.5"), the hybrid valuation approach uses the amount of additional throughput added to baseline throughput, relative to the amount of additional throughput simulated for "Point 3," to create a weight for the valuation based on additional throughput only. A weight for the extent of delay reduction enabled by NextGen at the "Point 2.5" operating scenario is constructed similarly, using the amount of reduction in average delay (from the level of average delay at the baseline simulation), relative to the amount of reduction in average delay achieved at the "reduce delay only, with no added throughput" operating point, "Point 2."

By creating this hybrid approach to benefit estimation, IPSA relies on a straightforward and continuous estimating function based on the valuations for the two "extreme" "increase throughput only" and "reduce delay only" approaches to simulating NextGen's impacts on user possibilities.

Key

- •A annual throughput, baseline feasible (Point 1)
- • a average delay, baseline infrastructure with feasible throughput (Point 1)
- • b average delay, NextGen infrastructure with baseline throughput (Point 2)
- •C annual throughput, NextGen infrastructure at approximate level of average delay *a* (Point 3)
- • *x* average delay associated with Point 2.5
- • Y annual throughput associated with Point 2.5



Valuation

•Using the reduction in average delay associated with operating unchanged throughput through a more capable NextGen system, the passenger value of time (PVT) and the average operating costs of airlines (ADOC), the value of time savings at Point 2 is denoted **VT**

•Using the reduction in average real yield associated with taking increased throughput to market, the value to passengers at Point 3 is the aggregation of savings on RPMs sold at reduced average real yield (the *consumer* surplus method), denoted **CS**

•The value of capabilities and operational outcomes leading to Point 2.5 is calculated as a weighted sum of these two "corner" valuations:

$$Value(2.5) = \left[\left(\frac{a-x}{a-b}\right)VT\right] + \left[\left(\frac{Y-A}{C-A}\right)CS\right]$$

Figure 3 Summary of "Hybrid" Valuation Approach for Monetizing NextGen Benefits in the Domestic Passenger Sector

VI. Environmental Analysis

The NextGen Vision 100 legislation requires the JPDO partnership to minimize the environmental impacts of aviation growth to society while at the same time develop a system that enables substantial traffic growth. The JPDO environmental result measures and monetizes the impacts of local air quality, climate change and noise levels near major airports and compares a NextGen scenario to a baseline or "no action" scenario. The measured results were then provided to the FAA who monetized the impacts. Table 2 provides an overview of the three categories examined including their physical and monetized definitions. This is part of an on-going effort to consistently evaluate environmental performance of NextGen as envisioned operational and technological improvements evolve, and as different levels of feasible traffic growth are explored.

Table 2 Summary of Environmental Metrics

Impact type	Effects modeled	Primary Metrics	
		Physical	Monetary
Climate	CO_2 "Non-CO_2": Cirrus, Sulfates, Soot, H_2O, Contrails (Note: No NO_x effects modelled)	Globally-averaged surface temperature change	Net present value of socio-economic damages
Air Quality	Secondary PM by NO_x and SO_x	Incidences of premature mortality	Net present value of health risks
Noise	Population exposure to noise, number of people annoyed Housing value depreciation, rental loss	Number of people within 55 dB DNL contour	Net present value of housing depreciation

Measuring the Physical Effects

The environmental analysis focused on the 2025 future conditions represented in the Baseline and NextGen scenarios. Many of the improvements related to environmental impact are captured as results of the operational simulations and reflected in the trajectories and flight times that feed the environmental models. However, within the terminal area where the local effects are sensitive to airspace and airport use, the simulation data was augmented to include higher fidelity trajectories. The Baseline scenario was derived from a 30-day radar data sample which was assumed to represent appropriate traffic variability and weather conditions. From this data we derived time of day usage, fix loadings, runway use, and primary airport configurations. For the NextGen Initial Alternative, there are three additional improvements modeled specifically for the environment. Two of these, Continuous Descent Arrivals (CDA) and Required Navigation Performance (RNP), deal with the specifics of the terminal area modeling, while the third, fleet technology improvement, deals with the retirement of older aircraft, and introduction of quieter, more efficient aircraft.

In order to include RNP and CDA-like procedures at the Continental United States (CONUS) OEP airports, two key assumptions were made. First it was assumed that all aircraft originating or destined for these airports were appropriately configured with the proper aircraft navigational equipment, and that both RNP and CDA procedures would be overlays of the existing terminal procedures. This allowed the approach to leverage existing radar data for determining flight paths and lessened the need for airspace redesign, which can be highly controversial and can require a more detailed analysis for each region that is being modeled. These assumptions seem to be consistent with existing practices for defining new Area Navigation (RNAV)/RNP and CDA procedures today. Note that this approach does not attempt to resolve conflicting procedures that may intersect due to the change in vertical profile caused by implementation of the CDA. The details for each procedure are provided below:

- RNP levels modeled are 0.15 for final approach and 0.5 for the terminal area. Terminal area data for each of the OEP airports are modified to reflect these values prior to environmental modeling. We apply the RNP values to the existing traffic patterns in such a way that the modified traffic flows have the same centerline as current flows. Centerlines are defined by traffic density.

- CDAs are modeled from 10,000 feet Above Field Elevation (AFE) to the runway. Descent angles of 2.5 degrees (from 10K ft to 6K ft) and 3.0 degrees (from 3K ft to the runway) are applied to all aircraft.

In the NextGen Initial alternative it was also assumed that all aircraft that entered the fleet in 2016 and later, met a goal equal to the NASA N+1 targets (which are also consistent with the FAA's CLEEN program). Table 3 provides details on the modeled aircraft performance associated with NASA N+1 and NASA N+2 technologies.

NAS
Dele

CORNERS OF THE TRADE SPACE	N+1 (2015 EIS) Generation Conventional Tube and Wing (relative to B737/CFM56)	N+2 (2020 IOC) Generation Unconventional Hybrid Wing Body (relative to B777/GE90)
Noise	- 32 dB (cum below Stage 4)	- 42 dB (cum below Stage 4)
LTO NOx Emissions (below CAEP 6)	-60%	-75%
Performance: Aircraft Fuel Burn	-33%**	-40%**

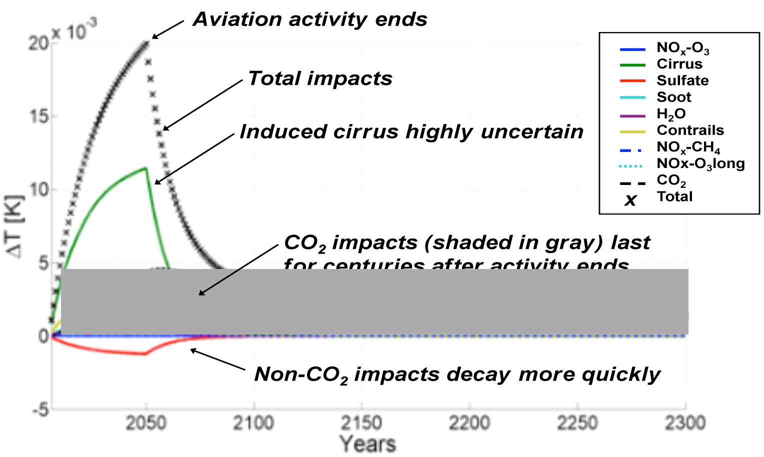
Table 3 NASA N+1 and N+2 Aircraft Performance Targets

Measuring the Monetary Impacts

While accepted methods for measuring the effects of noise and local air quality have been applied for a number of years, measuring the impact and valuation of climate change is a relatively new metric to be included as part of a societal assessment. The common factor for aviation noise and emissions is their cost to health and welfare, and hence monetization approaches are adopted consistent with EPA guidelines. The need to quantify climate impacts is understood (per DOT Federal Register instruction), but the values and some specific aviation impacts are still uncertain. In particular, how to value and assess climate change from greenhouse gases is still a highly debated issue. These gases stay in the environment for hundreds of years, as shown in Figure 4, and even small changes can have large impacts, as indicated in the following excerpt from an LMI report. "Although greenhouse gas emissions (GHGs) are trace gases in the atmosphere, measured in parts per million, parts per billion, or parts per trillion, these small concentrations regulate the global climate system (details shown in the following table). It is precisely because they are found in such small quantities that it is possible for human activities to change their concentration" (A Federal Leader's Guide to Climate Change, LMI, p.7).

NAS
Dele

To estimate the cost of the gaseous pollutants in terms of a value in today's terms or dollars, a discount rate is applied, as with any traditional cost and benefit analysis. As a result of the extended duration of climate effects, their valuation is extremely sensitive to the discount rate applied. The monetized results for the Overall Societal/Passenger case will employ more than one discount rate to make this sensitivity explicit.



2

Figure 4 Aviation Impacts on Climate (45-year scenario)

VII. Cost Analysis

This section describes the approach taken by the JPDO to develop the NextGen Lifecycle Cost Analysis. The cost analysis process incorporates data from Partner Agencies, commercial industry, and the airports community in the development of lifecycle cost estimates. The process also incorporates uncertainty and programmatic risk considerations. The specific scope of analysis is described below as is the structure by which the cost analysis is segmented. Stakeholders impacted by the technology and infrastructure improvements associated with NextGen are also identified. This section concludes with a listing of limitations and constraints that influence the confidence in the accuracy of the cost estimates presented in this report. Lastly, an evaluation is made concerning the maturity of the Lifecycle Cost Analysis LCCA in accordance with parameters defined by the Government Accountability Office (GAO).

JPDO established a step-by-step process to develop the NextGen Lifecycle Cost Analysis. This cost analysis process enables the JPDO to pilot, test, and document its methodology, data, and results. Additionally, this analytical process allows the JPDO to gather lessons learned in order to improve each subsequent version of the overall NextGen Lifecycle Cost Analysis. Figure 2 1 illustrates the cost analysis process, which is based on the Society of Cost Estimating and Analysis (SCEA) best practices.

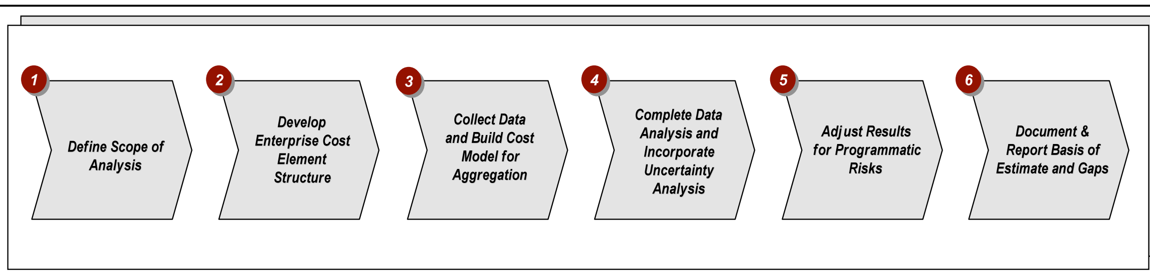


Figure 5 JPDO Cost Analysis Process

The process also includes a full set of documented assumptions. Every stage of the process involves collaboration, review, and input from federal agency partners and industry. In some cases, the information was collected from Partner Agencies and in other cases, a combination of industry research and subject matter knowledge was used to develop cost estimates for specific parts of NextGen. Over the last year, the JPDO achieved this collaboration by working with subject matter experts and coordinating with key offices in the FAA and NOAA. In the future, the JPDO plans to work more directly with other Partner Agencies, such as DoD and DHS, to refine the analysis of costs for NextGen. The cost analysis process includes a step for adjusting cost results for programmatic risks. However, this year no programmatic risk adjustment is being made to the estimate as discussed in Section 3.4.

The JPDO Cost Analysis Process for NextGen is comprised of six steps, beginning with defining the scope of analysis and culminating in the documentation of results:

Step 1: Define Scope of Analysis

The first step of the lifecycle cost analysis process focused on developing an understanding of the basic NextGen technologies and improvements proposed in order to define and document the scope of the cost analysis. Activities in this phase include working with key stakeholder personnel to identify and document assumptions, as well as determining reporting requirements. The definition of scope is a critical initial activity when developing a cost estimate and the success of any Lifecycle Cost Analysis is dependent on a clearly defined scope and set of expectations.

It is important to distinguish between the scope of NextGen used to develop costs and the scope or vision for all of NextGen. The JPDO planning documents – including the NextGen ConOps, EA and IWP – reflect the current vision for NextGen. The scope of the cost analysis is a "version" of NextGen, referred to as the "Initial Alternative". The Initial Alternative is based on a set of guiding assumptions developed to generate a plausible NextGen architecture and implementation path. This portfolio represents one unique grouping of relevant OIs, Enablers, and other planning elements from the NextGen EA and the IWP.

Step 2: Develop Enterprise Cost Element Structure

The next step in the cost analysis process was to develop a Cost Element Structure (CES). The CES – a series of cost categories and types – defines the list of cost elements required to fully document the lifecycle costs of any investment. It promotes consistency in preparing and displaying estimates, and captures all costs, direct and indirect, recurring and nonrecurring, throughout the NextGen evaluation period.

Relevant cost elements associated with NextGen include, but are not limited to: research and development, planning, acquisition and implementation of systems or solutions, and recurring activities associated with operating and maintaining systems or solutions.

Table 2 1 shows the high level cost elements of the estimate and descriptions for the types of costs included.

Table 4 Enterprise Cost Element Structure for NextGen Lifecycle Cost Analysis

CES	Description
1.0 Planning, Research and Development	Includes the cost of planning activities related to the overall administration and management of a project. This includes technical and administrative planning, coordination and control, and technical studies, as well as research and development activities.
2.0 Acquisition and Implementation	Reflects the cost of acquiring and developing systems and/or equipment. This includes costs associated with planning and managing deployment, such as site preparation and installation.
3.0 Operations and Maintenance	Addresses all recurring costs associated with the ongoing resources needed to operate and maintain infrastructure, equipment, and/or systems.

Step 3: Collect Data and Build Cost Model for Aggregation

This step included identifying and documenting the broad set of cost data sources, interacting with appropriate points of contact and subject matter experts such as researchers, Federal program personnel, academics, etc., and gathering existing cost information. This step also included generating initial cost estimates. The following data sources were used:

- Official investment and project documents from the FAA Joint Resources Council (JRC) process, such as program specific lifecycle cost estimates, bases of estimate and investment review briefings
- Project and implementation plans and/or schedules developed by program offices within the partner agencies
- Official budget documents, such as the Capital Investment Plan (CIP) developed by the FAA
- Cost estimates prepared by partner agencies and other organizations
- Various government and industry publications, circulars and reports, such as FAA Advisory Circulars and Bureau of Transportation Statistics (BTS) publications

Work sessions and meetings were held in collaboration with partner agencies and subject matter experts to review data, confirm preliminary assumptions and reach consensus on estimates to be used in the analysis. For this version of the LCCA, JPDO worked primarily with FAA's Air Traffic Organization – Finance (ATO-F) and Air Traffic Organization – NextGen and Operations Planning (ATO-P) to collect cost information associated with near- and mid-term NextGen programs as a preliminary step.

Dynamic models were then developed to calculate lifecycle cost estimates. Data collected from partner agencies and other sources was normalized and aggregated within a series of cost models. Based on the relationships between multiple economic parameters, unit costs, quantity, and duration inputs, the cost models were used to calculate the investment and recurring costs associated with NextGen from FY 2010 through FY 2050.

Step 4: Complete Data Analysis and Incorporate Uncertainty Analysis

Cost estimates, by their nature, are uncertain because they project the future. Uncertainty analysis was used to address this issue by estimating the range of potential cost outcomes (i.e., translating point estimates into estimated low and high cost ranges). Uncertainty analysis adjusts for the state of being unsure, including the inherent difficulties of predicting final costs, such as imprecise technology specifications or poor quality of analogous cost data. The NextGen uncertainty analysis is based on the Association for the Advancement of Cost Engineering (AACE) ranges for estimate uncertainty. The ranges are applied to costs in the CES based on specific AACE guidelines, which consider the characteristics of an estimate such as the methodology used to develop costs and the end usage of the estimate (e.g., concept screening, study or feasibility, budget, etc.).

Step 5: Adjust Results for Programmatic Risks

Once cost estimates have been aggregated and uncertainty has been incorporated, figures were adjusted based on the analysis of programmatic risks. Risk analysis for the NextGen cost analysis is consistent with the overall JPDO Risk Management Process, which is comprised of the following four steps:

- Risk Identification – Conduct structured interviews of subject matter experts to identify and document potential adverse events with a quantifiable impact, defined as risks. Risk events that have already occurred or are sure to occur (100 percent likelihood) are defined as issues. Risk events that are not currently quantifiable due to insufficient information or too much uncertainty are defined as concerns. Both issues and concerns are tracked in separate registries as part of the risk monitoring step.
- Risk Analysis – Categorize the likelihood and potential consequence of the event based on explicitly defined scales. Heuristics are followed to consistently translate the likelihood and consequence into a probabilistic influence on the cost estimate. A Monte Carlo simulation is used to aggregate the influence of the risks on the lifecycle cost estimate.
- Risk Mitigation – Develop strategies for reducing the influence of risk, assessing the effectiveness and cost of various mitigation strategies, and developing specific actions to mitigate the risks. Implementing risk mitigation plans will decrease the expected adverse influence of the event.
- Risk Monitoring – Track and report the status of risks

Only the Risk Identification and Risk Analysis steps were conducted as part of this LCCA. Data from these two steps will be used in the future to adjust the cost estimates. The adjustment of costs for programmatic risks is a standard step in the development of lifecycle cost estimates for large programs, and is part of the JPDO's own cost

analysis process. However, this version of the LCCA contains only a set of initially-identified risks, but does not provide risk-adjusted estimates of future NextGen costs. Future versions of this report will provide risk-adjusted cost estimates.

Step 6: Document and Report Basis of Estimate and Gaps

Using the outputs of the analyses conducted, the final step of the Cost Analysis process included documenting estimate results, along with an assessment of the cost maturity. Cost maturity evaluates not only the level of completeness in costs developed, but also the degree of rigor in the underlying source data. Data sources and assumptions (such as the effect of inflation applied to cost figures) were documented along with insights and findings from the analysis. A "basis of estimate" was generated that documents limitations, constraints, and any gaps or 'workarounds' used while generating the Lifecycle Cost Analysis.

This step also included communicating interim results to various NextGen stakeholders, documenting lessons learned, as well as capturing feedback from Partner Agencies and industry stakeholders, and reporting progress on the NextGen lifecycle cost analysis at key milestones.

VIII. Risk Analysis

Uncertainty and risk analyses are critical components of the portfolio analysis. Uncertainty analysis adjusts for the indefiniteness of the program outcome, including the inherit difficulties predicting final costs. Programmatic risk analysis adjusts for a broad set of potential adverse events that may prevent NextGen from achieving performance, cost, schedule and/or policy goals.

Because of the complex nature of the NextGen program (refer to NextGen Complexity Analysis Appendix), each cost module has a different level of maturity depending on the quality and sources of the underlying cost data, and on the degree to which NextGen capabilities have been defined by the JPDO for that module or functional area. The uncertainty analysis addresses the varying quality of the underlying information. The JPDO adheres to industry best practices – such as the use of SCEA and AACE standards – to define the expected accuracy range of the cost estimates.

Programmatic risk analysis accounts for potential adverse events that are not addressed by uncertainty analysis. The JPDO has developed an initial understanding of risks to the portfolio to enable making appropriate risks adjustments to future lifecycle cost estimates. Nevertheless, limitations stem from the developmental status of the NextGen program and its risk management:

- Additional risks with varying degrees of severity will certainly be identified as the program develops and further details regarding research, policy, technical requirements and other NextGen complexities becomes available.
- Risk adjustments cannot take account of benefits from mitigation because currently there is insufficient technical data. Typically after risk identification, project risks are analyzed and the analyzed risks are mitigated. The risk analysis is refined after considering risk mitigation. Insufficient data exists to assess the influence of risk mitigation efforts because JPDO risk mitigation efforts and analysis of ongoing activities that mitigate risks are in the preliminary stages.
- Adjustments for opportunities (as defined in the JPDO Risk Management Plan) have not yet been made. Opportunities that can be exploited would have the opposite impact of risks as they would decrease NextGen program costs or increase program benefits.
- Risk analysis only accounts for risks to the NextGen scope that has been estimated as part of the Initial Alternative.

Some of these influences are offsetting; however, the risk adjustment will become more accurate as more cost and technical data becomes available to address the influence of risk.

The JPDO has not yet made risk adjustments to the NextGen benefits and the estimates in the NextGen Lifecycle Cost Analysis Version 1.0. The JPDO has completed the initial foundation work for the risk adjustment by developing a process to identify, quantify and aggregate the influence of programmatic risks to the lifecycle cost estimates. Preliminary portfolio analysis risk identification activities have been completed and the likelihood and

cost impact of the identified risks have been assessed. However, the current assessment of identified risks reflects the worst case likelihoods and consequences, because the analysis has not yet considered the influence of ongoing risk mitigation activities. Adjusting the lifecycle cost estimates before considering the benefits of ongoing risk mitigation efforts would overestimate the potential cost risks. Therefore, the JPDO has deferred completing the risk adjustment to the lifecycle cost estimate until a deeper understanding of the identified risks and the influence of risk mitigation is possible.

While JPDO has not yet made risk adjustments to the lifecycle costs and benefits, the JPDO has completed several initial critical components of the risk analysis that enable more informed decision making. To date, JPDO has conducted an initial assessment of programmatic risk. Initially, JPDO has identified 98 risks that influence the Initial NextGen Alternative. The relative impact of the risks has been investigated and high impact risks have been identified. The JPDO cost risk analysis will support the portfolio analysis, and JPDO will adjust benefits and costs once ongoing risk mitigation efforts are incorporated into the analysis. Further information on the JPDO Portfolio Analysis risks can be found in the NextGen Lifecycle Cost Analysis Version 1.0.

IX. Next Steps in Developing the NextGen Business Case

In order to identify additional viable NextGen alternatives, an assessment of the costs, benefits and risks of varying equipage levels, performance levels, IOC dates, policy mandates, and risk exposures will be the focus of FY2010 JPDO business case activities.

A. Additional Alternatives

Although the IWP provides a complete high level picture of NextGen possibilities there are many different paths and trade-offs that need to be considered for an adequate assessment of NextGen and to clarify the possible implementation alternatives.

This analysis on additional alternatives focuses on evaluating the costs to major air traffic user stakeholders by focusing on some of the key implementation and investment factors that needs to be considered when deploying NextGen. These key questions are:

- Which operator groups need to have enhanced capabilities and in which locations?
- Which functional and performance requirements need to be met by location?
- Which operator groups will be required to meet which performance levels?

In summary, locations and operators may not require a uniform level of performance in all environments. The expected performance level, type of traffic, and the relative merits of a business case for individual aircraft and stakeholders should dictate the level of avionics needed. In some cases the risks and costs of achieving the highest level of performance by 2025 may not even be technically possible or required for many types of operations and stakeholders.

The methodology uses the IWP to define operational performance levels for the National Airspace System (NAS) based on a set of functional capabilities that can be obtained from specific investments in avionics and ground infrastructure. The JPDO has defined six performance groups, designated as NextGen Operational (NGOps) levels, which are sequenced so that higher operational levels require and build on the performance capabilities delivered from the lower levels. The functional capabilities delivered by each performance level are summarized in the table below.

Table 5 Additional Alternatives by NGOps Level

Operation Level	Time Fame	Technology and Capabilities
NextGen Operation Level – 1 (NGOps-1)	Near-Term (appox. Next 5 years)	• ADS-B Out – aircraft broadcasts position, velocity and other parameter to ground stations
NGOps-2	Mid-Term (aprox. next 5-10 years)	• Initial Data Link (CMU or FMS) • Optimal Profile Descents in Moderate Density • Widespread RNAV
NGOps-3	Mid-Term (appox. next 5 – 10 years)	• Initial Data Link (Integrated FMS) • Optimal Profile Descents in Moderate Density • RF (radius-to-fix) Legs or curved tracks to avoid conflicting airspace or terrain and closer routes
NGOps-4	Far-Term (approx. next 10 + years)	• CSPO (closely spaced parallel runway operations) and IMC CAVS (using conflict display of conditions in marginal weather conditions) • Enhanced Weather Information and DST (decision support tools)
NGOps-5	Far-Term (approx. next 10+ years)	• Optimal profile Descents in High Density Operations
NGOps-6	Far-Term (approx. next 10+ years)	• Separation by Automation

For the most part, the first three NGOps levels have been incorporated into the FAA budgeting and planning cycle through 2018. These performance levels build on the enabling deployment of ADS-Out which is identified in NGOps-1. In NGOps 2 and 3, situational awareness is not only available on the ground but begins to be integrated into the cockpit along with the gradual integration of digital information into the aircraft flight planning systems. This combination of technology allows aircraft equipped to these levels to fly more precise RNP routes and to operate in closer proximity on the surface and in terminal flight paths.

After NGOps 3, operations and procedures begin to use visual and digital information available to the crew and avionics systems to operate more efficiently in highly congested terminal areas. Using parallel approaches and eliminating some of the controls currently necessary in IMC (Instrument Meteorological Conditions), or less than optimal weather conditions, aircraft can operate in closer proximity in all phases of flight and conditions. For the highest levels of performance, NGOps-5 and 6, aircraft are controlled primarily by automation on the ground and digital information is completely integrated into the cockpit avionics and decision making technology. Aircraft will operate in a more autonomous manner than today by transmitting, receiving and integrating information from the other aircraft operating in the NAS.

There are several concerns and implications raised from an evaluation of the costs of complete implementation of NextGen capabilities by 2025. First, based on the current and expected fleet composition and the required avionics, complete NextGen compliance for all capabilities and stakeholders by 2025 may not be technologically feasible. In addition, even if it is technically possible the costs appear to be prohibitive. Requiring all High Performance General Aviation aircraft to equip is a primary contributor to this conclusion.

There are several alternatives available that lower the costs and risks associated with NextGen implementation. One is to consider delaying some of the advanced capabilities, so that the research and requirements can be finalized and also to incorporating avionics upgrades to meet advanced performance levels into the normal turnover cycle of aircraft retirements and purchases to the greatest extent possible. Avoiding retrofit to a minimum will significantly lower the economic impact to the users.

Another cost mitigation strategy is to use mixed performance and equipage levels so that capabilities are targeted to selected routes and airports. If performance levels are stratified by location, for example heavily congested airports or airspace, users can plan accordingly and purchase advanced equipage for only those aircraft where it makes sense from a business perspective.

B. Agency Analysis Issues and Gaps

While this document represents a significant step forward in the portfolio analysis capability at the JPDO and provides initial results and recommendations, it still excludes some key components of the NextGen IWP and their accompanying costs, benefits and risks. The following narrative explains some of the general and specific

stakeholder issues that need to be addressed in subsequent analysis to provide a more complete tradespace alternative perspective.

General Issues

- The JPDO has only begun to explore and provide information on potential alternative portfolios and implementation of NextGen.
- Benefits estimated do not include all operational improvements as identified in the IWP.
- Sensitivity analysis needs to be included to account for potential different air transportation futures, i.e, demand forecasts, fleet configuration, increased used of secondary airports, etc.
- The baseline future estimates of life cycle costs are not complete. Therefore the true incremental costs of operations and maintenance of NextGen for air transportation is not yet known.
- Security and safety costs and benefits need to be included as part of the portfolio analysis.

Stakeholder-Specific Issues

Commercial Aviation

- Airline Operating Center (AOC) costs are not estimated.
- New engine and airframe costs are not included.
- Assuming commercial airlines will use NextGen operational improvements to reduce flight time is only one possible manifestation of potential benefit. Individual commercial carriers could use NextGen benefits to change operations in many additional ways.

FAA

- Exploration into the implications of NextGen technology on controller productivity and staffing is needed.
- Investigatation into the potential costs and benefits of facility consolidation is needed.

DOD

- Data and information regarding all NextGen related investments and activities is needed (e.g., fuel efficiency gains, improvements related to SUA, equipage of existing aircraft).

NASA

- Advanced aircraft technologies are not incorporated into the analysis.
- Greater understanding of the full costs to implement research and development programs is needed (e.g., TRL levels).

DHS

- Data and information regarding all NextGen related investments and activities is needed.

NOAA

- Ancillary benefits are not included.
- Validation of benefits calculated for the implementation of net-centric weather to ensure the accuracy of results is needed.
- Additional costs pertaining to NextGen (e.g., high-end computing) are needed.

Cargo

- Consideration of the business case for cargo carriers is needed.

General Aviation

- Consideration of the business case for all general aviation, in addition to High Performance General Aviation, is needed.

Acknowledgements

The Interagency Portfolio and Systems Analysis Division would like to acknowledge the many persons within the JPDO as well as those representing Other Government Agencies, FFRDC's, academia, and industry who contributed to the Portfolio Analysis. The execution of the Portfolio Analysis would not have been possible without the combined expertise and extensive effort brought to bear by these multiple agencies, organizations, and personnel. The following is a table of authors whom directly contributed to the content of this study and report.

Name	**Organization**
Yuri Gawdiak	NASA, JPDO
Siddharth Gejji	Federal Aviation Administration
Gregory Carr	Sensis Corporation
George Hunter	Sensis Corporation
Kris Ramamoorthy	Sensis Corporation
Alex Huang	Sensis Corporation
Stojan Trajkov	Sensis Corporation
Shahab Hasan	Logistics Management Institute
Jeremy Eckhause	Logistics Management Institute
Robert Hemm	Logistics Management Institute
Dou Long	Logistics Management Institute
Jerry Creedon	Old Dominion University
Mike Marcolini	NASA Langley Research Center
Monica Alcabin	Boeing Commercial Aircraft
Mike Graham	Metron Aviation
Terry Thompson	Metron Aviation
Stephen Augustine	Metron Aviation
John DiFelici	Metron Aviation
Tyler White	Metron Aviation
David Ballard	GRA, Inc.
Rich Golaszewski	GRA, Inc.
George Price	Crown Consulting
EJ Spear	Mitre CAASD
Debby Kirkman	Mitre CAASD
Marc Narkus Kramer	Mitre CAASD
Steve Giles	Mitre CAASD
Sylvie Volel	Booz Allen Hamilton
Amit Kumar	Booz Allen Hamilton
Kevin Foley	Booz Allen Hamilton
Kent Duffy	Booz Allen Hamilton
Ian Capitelli	Booz Allen Hamilton
Jaquilyn Pak	Booz Allen Hamilton
Shawn Hansen	Booz Allen Hamilton